THE EFFECTS OF FOREST FIRES ON THREE SPECIES OF STICK INSECTS (PHASMATIDAE PHASMATODEA) OCCURRING IN PLAGUES IN FOREST AREAS OF SOUTH-EASTERN AUSTRALIA.

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(Plate iv.)

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Synopsis.

The effect on three species of phasmatids of forest fires, both "wild" or bushfires and controlled burning, practised as a sylvicultural technique in Forestry, is studied. Two field experiments using a controlled fire were carried out at Wedding Bells State Forest near Woolgoolga, N.S.W. (where *C. tessulatus* (Gray) is present) and at Konangaroo State Forest, near Jenolan, N.S.W. (where *P. wilkinsoni* Macleay and *D. violescens* (Leach) occur) in order to study the effect of such fires on the egg stage of these insects. The results of these were analysed and the conclusions reached as to their effects on this stage are presented.

Bushfires which occurred during 1957 in the Jenolan and Hanging Rock-Nundle State Forest areas were studied to determine their effects in the nymphal and adult stages of the stick insects and the results are discussed.

Conclusions drawn from the results of these experiments, field studies and observations made are as follows: (1) That unless a fire consumes the litter on the forest floor down to the mineral earth there will be little deleterious effect on either eggs containing developing embryos or the larvae of the *Myrmecomimesis* sp. wasp; (2) Fires affecting the nymphal or adult stages can operate as a destructive factor having a long-term depressant effect on phasmatid populations and can modify the forest stand to such an extent as to reduce such populations to a very low density; (3) That the effects of such fires will be dependent on a number of factors, including the intensity of the fire, the condition and type of the forest stand, and the litter on the forest floor.

Introduction.

Three species of stick insects occur in plague numbers in the forests of south-eastern Australia. The biology of *Ctenomorphodes tessulatus* (Gray) has been studied by Hadlington and Hoschke (1959) and that of *Didymuria violescens* (Leach) by Campbell (1960) and *Podacanthus wilkinsoni* (Macleay) by Richards (1953) and Campbell (1960).

The possible use of fire as a control measure was mentioned by Froggatt (1923) and since then its merits have been discussed without any effort being made to ascertain the truth of his proposition or the probable results of such a course of action.

In present-day forest practice "burning" presupposes that the fire will be "controlled" and not a "wild" or uncontrolled bushfire, although the effects of the latter are also considered in this paper.

Eggs of *C. tessulatus*, after being oviposited during the summer and early autumn, may be present on the forest floor for about six months and those of *P. wilkinsoni* and *D. violescens* for up to eighteen months or more. During this stage there may be several periods in autumn, winter and possibly early spring when controlled burning may be practicable and safe.

The active feeding stages (nymph and adult) are present during the spring, summer and early autumn and the safe use of fire as a possible control depends on the local weather and climatic conditions.

During the nymphal stage early spring is usually the only time when fire can be used safely unless the summer is wet or cool and then it may be impossible to light a fire in the forest for this purpose. It is usually unsafe to attempt the use of fire as a possible control during the adult life of the insects.

A "wild" fire may occur at any period of the year when conditions are favourable and from the point of view of its effect on a phasmatid population (or the individuals comprising it) it is of no consequence whether the fire is controlled or not. (The severity or consequences of a fire often have no relation to its classification.)

In an attempt to ascertain the effect of a controlled fire on the egg stage of these insects, two experiments were carried out. To assess the effect of a "wild" fire on both the egg and nymphal stages, sampling was done before and after the fire and subsequent observations were made also.

The experiments involving controlled burning of the undergrowth and surface litter on the forest floor were carried out:

(1) On Wedding Bells State Forest No. 360, near Woolgoolga in northern New South Wales, where eggs of *C. tessulatus* were present amongst the litter, on 20 and 21/5/57; and

(2) At Konangaroo State Forest No. 750, near Jenolan, N.S.W., on the central highlands, where eggs of *P. wilkinsoni* and *D. violescens* were present, on 11 and 12/7/57. The weather conditions during late autumn and early winter made these small controlled fires possible and safe.

Wedding Bells State Forest.

Procedure.

The area selected was in Compartment 6, at an altitude of 500 ft. It was triangular in shape, being bounded on two sides by roads and a firebreak was constructed by hoeing along its third side to prevent the fire from spreading.

The overstorey trees on this portion were *E. gummifera* (Gaertn.) Hochr. (bloodwood), *E. acmenioides* Schau. (white mahogany), *E. maculata* Hook. (spotted gum) and *E. paniculata* Sm. (grey ironbark), with an intermediate storey of *Casuarina torulosa* Ait. (rose sheoak) and an understorey of leguminous and proteaceous shrubs and grasses.

The area was divided into four roughly-equal blocks, and within each block five samples of litter down to (but not including) the mineral earth were collected at random. Each sample was one square yard in extent and all were beneath the crown projection of an overstorey tree.

After the fire was out and the area was cool, another twenty samples were collected. Each was the same size and immediately adjoining one of the previous samples.

All samples were later sieved and the eggs removed manually for examination under a low power stereo-microscope.

Conditions of Burn.

Weather conditions were warm and dry, the day cloudless and the litter very dry. Maximum shade temperature (measured in the open) was 78°F. at 2 p.m.

The fire was lit around the perimeter of the area and allowed to burn inward. From a fire protection viewpoint a good "controlled burn" was obtained and practically all grass, leaves and small fallen branches were reduced to ashes. However, the surface litter was burnt down to the mineral earth in a very patchy manner. There were no extensive areas of mineral soil exposed although the fire was hot enough to ignite the fibrous bark of a mahogany and sparks were carried by the wind beyond the road where spot fires were started.

Konangaroo State Forest.

Procedure.

The area selected, enclosed by a fire trail, was near the northern boundary of the forest adjoining the Jenolan State Park and east of the Oberon-Kanangra Walls Road at an altitude of 4,200 feet (see Pl. iv, fig. 1).

Overstorey species were *Eucalyptus radiata* Sieb. (peppermint), *E. viminalis* Labill. (manna gum), *E. dalrympleana* Maiden (mountain gum), *E. pauciflora* Sieb.

(snow gum), *E. dives* (Gaertn.) Hochr. (red bloodwood) and *E. fastigata* D. & M. (brown barrel), an understorey of *Eucalyptus* regeneration, *Lomatia myricoides*, *Pteridium aquilinum* (bracken fern), *Acacia falciformis* and *Dianella revoluta* was present with ground cover of *Poa* sp. (snow grass). This represents an example of Costin's (1954) *E. fastigata-E. viminalis* alliance.

Fourteen litter samples each one square yard in area were collected at random down to, but excluding, the mineral earth, before the fire was lit. After the area had cooled another fourteen samples were collected at random and the eggs later removed and examined as described above.

Conditions of Burn.

Weather conditions were dry but cool, 70°F. maximum in shade, as the sky was overcast with medium altitude cloud. The perimeter of the area was set alight and the fire allowed to burn inward. The fire burnt unevenly, but the areas from which the samples were taken (beneath the crown projection of trees with a reasonably heavy leaf litter and less grass than in the open) were in many cases well burnt and the mineral earth exposed.

Results.

The results of examination of the eggs collected from the samples are summarized in Table 1.

Table 1.

Total Number of Eggs Collected Before and After Controlled Burning.

	Advanced Embryos.		Undeveloped Embryos.	Parasitized Eggs.	Diseased or Deteriorated Eggs.	Total Eggs.	Empty Shells.	Grand Total.
	Live.	Dead.						
Wedding Bells S.F. (*C. tessulatus*) (20 plots)								
Before burning	13	1	9	225	759	1007	3449	4456
After burning	10	2	1	175 (9b)	925(1b)	1123	3486	4609
Konangaroo S.F. (*P. wilkinsoni*) (14 plots)								
Before burning	3	1	4	22	22	52	304	356
After burning	0	0	4 (4b)	0	9 (1b)	13 (5b)	166	184
(*D. violescens*) (14 plots)								
Before burning	1	0	15	27	59	102	920	1022
After burning	0	0	4 (1b)	12 (5b)	26 (3b)	42 (9b)	475 (42b)	568

" b " denotes burnt—i.e. contents affected by fire though state of egg still discernible.

Details are given in Appendix I and II.

C. tessulatus.

Analysis of the figures indicates that the burning had no significant effect on the eggs containing advanced embryos. Eggs in which embryonic development was at a very early stage and the larvae of the parasitic wasp *Myrmecomimesis* sp. present within the phasmatid eggs (Hadlington and Hoschke 1959) were significantly affected.

P. wilkinsoni and D. violescens.

In the case of both species, all classes of eggs were significantly affected by the fire.

Discussion.

The effects of the fire are apparently proportional to the amount of heat to which the eggs are exposed. These effects are influenced by: (*a*) Intensity of the fire; (*b*) Rate of spread of the fire; (*c*) Nature and quantity of litter on the forest floor; (*d*)

Conditions of the litter; (*e*) Disposition of the eggs in the litter; (*f*) History of defoliation of the area.

Defoliation at Wedding Bells S.F. had been extensive and the needles—branchlets with scale-like leaves—of *Casuarina* sp. as well as fragments of *Eucalyptus* sp. leaves covered the ground. The amount of litter covering the eggs depends largely on the time of oviposition and the rate of defoliation. Eggs with advanced embryos would be most deeply covered by litter as they were oviposited during defoliation. It is assumed that parasitized eggs in the litter, and probably less deeply covered by it, would be those most easily detected by the wingless *Myrmecomimesis* female. Eggs with little embryonic development were probably laid most recently and covered only by a small amount of litter.

At Wedding Bells the fire spread quickly over the area, burning the top surface of the litter but not affecting it except in localized spots to any depth. Eggs nearest the surface were affected significantly but a proportion of parasitized eggs and those deeply buried in the litter were undamaged.

At Konangaroo the fire was not as satisfactory a control burn as the one at Wedding Bells as it did not destroy the small or medium-sized branchlets. However, it did burn more slowly and thoroughly and generally burned the surface litter down to the mineral soil particularly, as mentioned earlier, where this was mainly composed of fallen leaves and bark. As all of the samples were collected under the crown projection of a tree, and the litter there had a higher proportion of this debris, the fire was usually most intense in these situations. However, it was a very uneven burn and large patches were left untouched. This slow fire which destroyed litter down to the soil damaged all classes of eggs significantly and even burnt empty shells which represented past populations and were deepest buried in the litter.

Effects of Fire on Nymphs and Adults.

Nymphs are present in spring and early summer and adults during summer and early autumn. In the highlands where plagues of these insects may occur, weather conditions must necessarily be dry and warm for a fire to spread extensively. Burning during such conditions, except for special purposes, is not favoured, because of the difficulty of control and emphasis is placed rather on the prevention and suppression of fire at these times. Consequently, no experimental burning was attempted during such conditions, for these obvious reasons.

During the early summer of 1957, however, "wild" fires burnt extensive forested areas near Jenolan and Nundle and various observations and records of their effects on the phasmatids were made.

Egg surveys to estimate the probable densities of phasmatid populations had been made in the Nundle group of forests, where plague numbers had been predicted as a result of these surveys (Campbell, 1960). Large numbers of nymphs of *P. wilkinsoni* were present as expected on Tuggolo, Tomalla and Nundle State Forests during the spring and early summer of 1957. Moderate numbers were present during the same period over portions of the Jenolan area.

Nundle Area.

During early November, 1957, partial defoliation of the trees was visible and the insects were in the second to fourth instars. On 17th November a "wild" fire burnt most of Tuggolo State Forest and subsequently portions of Tomalla and Nundle State Forests; it was not brought under control until 2nd December.

Conditions were very warm and dry and fire control operations were hampered by the steepness and inaccessibility of the terrain. The fire not only burnt along the ground but also burnt in the crowns of the trees in many cases (a "dependent-crown" fire). Litter, undergrowth and the crowns were consumed over extensive areas. On Tuggolo State Forest the fire, fanned by a strong southerly wind, burnt strongly at night as well.

The tree crowns within all these forests were mainly composed of epicormic shoots and these were present on many stems as a result of refoliation after previous severe defoliation by phasmatids in 1955/56. Where the insects were numerous they were present on the shoots on the stems as well as in the crown of the trees.

The fibrous bark of species such as *E. obliqua* and *E. laevopinea* and epicormic growth assisted the fire to reach the crowns.

Effects of Fire and High Temperatures.

The fire affected the phasmatids in various ways: (1) by direct destruction; (2) by "knock-down" from heat or smoke followed by burning of undergrowth or litter onto which the insects fell; and (3) by killing by high temperature without direct contact with the fire.

The insects can withstand high temperatures for short periods without being killed, although at both Epping and Hurstville (suburbs of Sydney, N.S.W.) when the ambient air temperature reached 108°F. in the shade for an hour or so on 20th December, 1957, deaths of *D. violescens* and *P. wilkinsoni* (held in wire mesh cages) ensued. *C. tessulatus* withstood this temperature (unpublished reports Hadlington and Campbell, 1957).

During December, 1951, it was observed that adults and nymphs of *P. wilkinsoni* were killed at Nundle S.F. while crossing bare open ground (a bush fire was burning at this time) and specimens kept in the cabin of a truck in which the temperature was recorded at 150°F. lived for 15 minutes (personal communication, P. Hadlington).

Table 2.

Total Numbers of Eggs of P. wilkinsoni *Collected by Sampling on Tuggolo S.F. Before and After the Fire of 1957.*

	Number of Sites Sampled.	Advanced Embryos.		Undeveloped Eggs.	Parasitized Eggs.	Diseased or Deteriorated Eggs.	Total.	Empty Shells.	Grand Total.
		Live.	Dead.						
Before fire 1957..	9	217	0	100 (1)	91	346 (7)	754 (8)	386 (60)	1140 (68)
After fire 1959 ..	6	3	1 (1)	2	0	14	20 (1)	87 (1)	107 (2)

Figures in brackets denote eggs of *D. violescens*.

In 1957 it was observed that temperatures which scorched (and so killed) leaves also killed *P. wilkinsoni*, but some survivors fed for at least a week after a part of their abdomen was burnt off.

Adult insects are disturbed by smoke and will move from the tree crowns by falling or flying in advance of any marked increase of ambient temperature caused by the approach of a fire, thus increasing the chances of their destruction by flames or heat. In 1951, at Nundle, phasmatids were observed to be killed by heat 400 yards in advance of a fire.

In 1957 fire caused almost complete destruction of the phasmatid *P. wilkinsoni* population which was present in very high density on Tuggolo State Forest, as is illustrated by comparison of the numbers of eggs obtained by sampling this forest in 1957 and 1959. The sites were chosen quite at random — those sampled in 1959 do not coincide in every instance with those of 1957 — details are given in Appendix III.

A potential phasmatid population at eclosion within the range of 3,000-360,000 nymphs per acre was predicted in 1957 and in 1958 a population at eclosion within the limits of 9,000-110,000 nymphs per acre could be expected. In other words, severe to total defoliation would be expected over the whole of this forest in 1957 and some defoliation, serious only in very localized situations, would occur in 1958 also.

Prior to the fire in 1957 serious defoliation was occurring as predicted and observations made revealed a pattern of population density which agreed satisfactorily with the forecast made (Campbell, 1960).

After the fire it was difficult to find a live phasmatid, even in areas where they had been most numerous, and there was no doubt of the extremely high mortality which had been caused as a direct and indirect result of the fire.

In 1959 the area was again sampled and examination of the eggs obtained indicated that a population of between 0-6,000 to the acre could be expected in 1959/60 and between 0-3,000 per acre in 1960/61. Observations made in 1960 confirmed the forecast for that year.

These figures and observations strengthen the observations made in 1957 of the catastrophic effect of the fire on the phasmatid population in this forest.

By the end of April, 1958, it was difficult to distinguish between the burnt and unburnt portions of the forest, as defoliation, by the phasmatids, of the unburnt area was almost total. The main observable difference was the blackened trunks and lack of any undergrowth in the burnt areas. Recovery of the trees in the burnt area has also been more rapid than those in the area defoliated by the insects.

Jenolan Area.

Damage to the forests of this region by phasmatids (mainly on areas not dedicated as State Forest) was, and is, probably the most serious of any in the various localities affected (see Pl. iv, figs 2, 3).

Both *P. wilkinsoni* and *D. violescens* have occurred in very large numbers during recent years and large numbers of many *Eucalyptus* species have been killed and others severely damaged by defoliation over many thousands of acres. Most of the timber is of little commercial value, but much of the area represents a portion of the high rainfall area of the catchment for the new Warragamba Dam on the Wollondilly River in New South Wales (Holford, 1959).

Serious landslip and erosion occurred soon after because of removal of the Eucalyptus canopy by defoliation on the very steep country around Jenolan. This was later minimized by stabilization of the area by the growth of tree regeneration, herbs and grass cover.

Early in November, 1957, a severe uncontrolled fire burnt large areas of forested land supporting fairly dense populations of phasmatids either as nymphs feeding on the foliage or as egs present amongst the forest litter. This fire burnt for several weeks until controlled near Jenolan Caves on 30/11/57. As a result of this fire, which resulted in the destruction of the stabilizing ground cover, as well as defoliation of the remaining live *Eucalyptus* sp., severe land slip and erosion again occurred on the steep slopes.

Very high mortality of the phasmatid population occurred and in 1959/60 (when high numbers would normally have been expected) it was difficult to find, even by careful searching, a few phasmatids where they had been previously abundant. This region, throughout which very dense populations of phasmatids occurred, extending along the forested highlands from Wallerawang to Wombeyan, N.S.W., now contains only one small area where phasmatids are now present in high numbers. This is situated about five miles north-west of Wombeyan Caves, N.S.W., on the Great Dividing Range. This area was not burnt in 1957.

Discussion.

It appears from the evidence available, that forest fires have considerable and important effects on phasmatid populations. The most obvious effect is that of destruction of large numbers of phasmatids. Occasionally the environment is modified to the extent of changing it completely to one in which the species cannot persist, as repeated firing of the forest area will convert it into open savannah or grassland for varying periods of time.

During the current plagues of *P. wilkinsoni* (Campbell, 1960) fire has caused a crash of the population in three instances. In the case of this insect which was

extremely numerous in the Duncan's Creek area of Nundle S.F., a severe fire occurred in 1951. Since then the density of the population has been very low indeed and has not since built up to plague proportions. During 1957 when numbers were very high in the State Forests of Nundle, Tomalla and Tuggolo and in the Jenolan area, serious fires occurred as mentioned previously.

Since then numbers have been very low in all areas burnt over by these fires.

The other population crashes are attributable to exhaustion of the food supply at Nundle during 1952 and 1957 (Campbell, 1960). The only areas where *P. wilkinsoni* is abundant at present are those which were not burnt in 1951, or 1957, or which were not completely defoliated in 1957. There was a recovery of the population in the areas where the crash occurred, due to the exhaustion of food at Nundle in 1952, during the period 1953-1957 but there has been no recovery to date of the population in the Duncan's Creek area after the 1951 fire. The effects of fire are probably longer lasting than the effects of exhaustion of the food supply.

This wild fire described above occurred during the end of the nymphal stage of the phasmatids; the adult insects are knocked down by smoke and there is no evidence to suggest they are any less susceptible than the nymphs.

The effects of fires occurring when the phasmatids are in the egg stage are far more complex. These are influenced by the weather conditions, condition and type of the undergrowth and forest litter, and the disposition of the eggs within the litter and on the forest floor, as well as the stage of development of the embryo.

It is also possible that non-lethal high temperatures may disturb the normal development of the embryo and cause eclosion of the nymphs at a time when it would not generally occur. *P. wilkinsoni* was unusually abundant, in small unburnt localities, in the summer of 1958/59, following the 1957 fire at Jenolan, but present in low numbers in the summer of 1959/60 when it was anticipated that they would be abundant.

The effects of fire on the cleptid wasp egg-parasite may be completely destructive (Hadlington and Hoschke, 1959) but, as with the unparasitized eggs, the effects are complex.

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References.

Campbell, K. G., 1960.—Preliminary Studies in Population Estimation of two species of Stick Insects (Phasmatidae Phasmatodea) occurring in plague numbers in highland forest areas of south-eastern Australia. Proc. Linn. Soc. N.S.W., 85: 121-137.

Costin, A. B., 1954.—A study of the Ecosystems of the Monaro Region of N.S.W. *Govt. Printer, Sydney.*

Froggatt, W. W., 1923.—Forest Insects of Australia. *Govt. Printer, Sydney*: 57-59.

Hadlington, P., and Hoschke, F., 1959.—Observations on the Ecology of the Phasmatid, *Ctenomorphodes tessulata* (Gray). Proc. Linn. Soc. N.S.W., 84: 146-159.

Holford, I. C. R., 1959.—A Climatological Study of Warragamba Catchment Area. *Jour. Soil Cons. Serv. N.S.W.*, 15 (1): 34-60.

Richards, M., 1953.—An enemy of our Eucalypt Forests, the Plague Phasmid *Podacanthus wilkinsoni* Macl. *Division of Wood Technology, Forestry Commission of N.S.W.* Tech. Notes, 6 (3-4): 11-16.

EXPLANATION OF PLATE IV.

1.—Area controlled burned on left-hand side of car. Note some trees still living in this section — Konangaroo State Forest. (Photo, K. G. Campbell.)

2, 3.—Trees defoliated completely and repeatedly by phasmatids killed outright — Konangaroo State Forest. (Photo, P. Hadlington.)

APPENDIX I.

Konangaroo Burning Experiment.

Site No.	Before Burning—11/6/57.																After Burning—12/6/57.															
	Advanced Embryos.				Undeveloped Embryos.		Parasitized Eggs.		Diseased Eggs.		Total.		Empty Shells.		Grand Total.		Advanced Embryos.				Undeveloped Embryos.		Parasitized Eggs.		Diseased Eggs.		Total.		Empty Shells.		Grand Total.	
	Alive.		Dead.														Alive.		Dead.													
	P.	D.	P.	D.	P.	D.	P.	D.	P.	D.	P.	D.	P.	D.	P.	D.	P.	D.	P.	D.	P.	D.	P.	D.	P.	D.	P.	D.	P.	D.	P.	D.
1	—	—	—	—	—	—	3	6	2	11	5	17	28	108	33	125	—	—	—	—	—	—	—	—	3 (1b)	—	3	—	31	15	35	15
2	—	—	—	—	—	—	2	1	2	4	4	5	32	37	36	42	—	—	—	—	—	—	—	1 (1b)	3	4	3 (1b)	5 (1b)	49	40	52	46
3	1	1	—	—	—	6	2	3	3	3	6	13	73	29	79	42	—	—	—	—	—	—	—	—	—	—	—	—	9	13	9	13
4	—	—	—	—	1	2	3	3	4	—	8	5	27	36	35	41	—	—	—	—	—	1	—	5 (1b)	1	4 (1b)	1	10	12	14	13	26
5	—	—	—	—	—	1	—	3	1	7	1	11	7	40	8	51	—	—	—	—	—	—	—	—	—	2	—	2	15	68	15	70
6	1	—	—	—	1	3	4	6	1	22	7	31	41	188	48	219	—	—	—	—	—	—	—	—	1	—	1	10 (2b)	6	24	7	24
7	—	—	—	—	—	—	—	—	—	2	0	2	14	96	14	98	—	—	—	—	—	—	—	—	—	1	—	1	1	7	1	8
8	—	—	—	—	—	1	3	3	1	1	4	5	6	17	10	22	—	—	—	—	—	—	—	—	—	1	—	1	4	39	4	40
9	1	—	1	—	1	1	1	—	3	3	7	4	24	48	31	52	—	—	—	—	—	—	—	—	—	2	—	2	5	26	5	28
10	—	—	—	—	—	1	—	1	—	3	0	5	3	50	3	55	—	—	—	—	—	—	—	—	—	2 (1b)	—	2 (1b)	2	5	2	8
11	—	—	—	—	—	—	2	1	—	1	2	2	5	12	7	14	—	—	—	—	—	—	—	1	—	2	—	3	6	73	6	76
12	—	—	—	—	—	—	—	—	1	—	1	0	6	24	7	24	—	—	—	—	—	—	—	—	—	1	—	1	3	11	3	12
13	—	—	—	—	—	—	2	—	4	2	6	2	17	108	23	110	—	—	—	—	4 (4b)	1	—	2	—	3	4 (4b)	6	19	59 (10b)	27	75
14	—	—	—	—	1	—	—	—	—	—	1	0	21	127	22	127	—	—	—	—	—	2 (1b)	—	3 (3b)	1	4 (1b)	1	9 (5b)	4	81 (32b)	5	127
	3	1	1	—	4	15	22	27	22	59	52	102	304	920	356	1022	—	—	—	—	4 (4b)	4 (1b)	—	12 (5b)	9 (1b)	26 (3b)	13	42 (9b)	166	475 (42b)	184	568

Note: (b) denotes burnt, i.e. contents affected by fire though state of egg still discernible.
P = *P. wilkinsoni.*
D = *D. violescens.*

APPENDIX II.

Wedding Bells State Forest.

Site No.	Before Burning—20-21/5/57.								After Burning—20-21/5/57.							
	Advanced Embryos.		Undeveloped Embryos.	Parasitized Eggs.	Diseased or Deteriorated Eggs.	Total.	Empty Shells.	Grand Total.	Advanced Embryos.		Undeveloped Embryos.	Parasitized Eggs.	Diseased or Deteriorated Eggs.	Total.	Empty Shells.	Grand Total.
	Live.	Dead.							Live.	Dead.						
1a	—	—	—	8	41	49	102	151	—	—	—	3	38	41	144	185
b	—	—	—	6	32	38	152	190	—	—	—	2	37	39	126	165
c	—	—	1	—	18	19	52	71	—	—	—	2	24	26	115	141
d	—	—	—	1	7	8	78	86	—	—	—	37 (1b)	44	81 (1b)	255	337
e	—	—	—	12	34	46	108	154	—	—	—	6 (1b)	76	82 (1b)	205	288
Total 1 ..	—	—	1	27	132	160	492	652	—	—	—	50 (2b)	219	269 (2b)	845	1116
2a	1	—	—	4	13	18	155	173	—	1	—	8 (6)	68	77 (6b)	316	399
b	—	—	1	11	5	17	170	187	—	—	—	2	77	79	306	385
c	—	—	—	—	—	0	62	62	—	—	—	3	70	63	198	261
d	—	—	—	34	68	102	276	378	1	—	—	17	73 (1b)	91 (1b)	172	264
e	—	—	—	2	27	29	125	154	2	1	—	22	60	85	321	406
Total 2 ..	1	—	1	51	113	166	788	954	3	2	—	52 (6b)	338 (1b)	395 (7b)	1313	1715
3a	—	—	—	8	34	42	176	218	—	—	—	—	7	7	41	48
b	—	—	—	22	86	108	219	327	1	—	1	4	19	24	105	130
c	1	—	1	29	68	99	337	436	—	—	—	9 (1b)	65	74 (1b)	130	205
d	—	—	1	7	19	27	76	103	1	—	—	11	17	29	100	129
e	—	—	—	4	12	16	152	168	2	—	—	29	32	63	238	301
Total 3 ..	1	—	2	70	219	292	960	1252	4	—	1	53 (1b)	140	197 (1b)	614	813
4a	3	—	3	13	9	28	201	229	—	—	—	3	9	12	60	72
b	1	—	—	6	58	65	104	169	—	—	—	4	83	87	204	291
c	2	1	1	15	26	45	152	197	1	—	—	5	56	62	207	269
d	1	—	—	19	80	100	347	447	1	—	—	6	19	26	100	126
e	4	—	1	24	122	151	405	556	1	—	—	2	61	64	143	207
Total 4 ..	11	1	5	77	295	389	1209	1598	3	—	—	20	228	271	714	965
Total ..	13	1	9	225	759	1007	3449	4456	10	2	1	175 (9b)	925 (1b)	1132 (10b)	3486	4609

(b) denotes burnt, i.e. contents affected by fire though state of egg still discernible.

APPENDIX III.

Figures of Egg Dissections of Survey made 3–6/6/1957: Tuggolo State Forest (P. wilkinsoni).

Site No.	Advanced Embryos.	Developing Embryos.	Undeveloped Eggs.	Parasitized Eggs.	Diseased and Deteriorating Eggs.	Total.
1	1	—	6	—	9	16
2	4	—	9	—	16 (1)	29 (1)
3	11	—	7	3	41 (3)	62 (3)
4	29	—	9	10	39 (1)	87 (1)
5	4	—	6	7	8	25
6	15	—	3	4	5	27
7	13	—	16	13	15 (1)	60 (1)
8	119	—	36 (1)	45	197 (1)	402 (2)
9	13	—	8	9	16	46
Total	217	—	100 (1)	91	346 (7)	754 (8)

Egg Survey 14–17/9/1959—Tuggolo State Forest.

Site No.	Developed Embryos.		Undeveloped Embryos.	Parasitized Eggs.	Diseased or Deteriorated Eggs.	Total.	Empty Shells.	Grand Total.
	Live.	Dead.						
1	—	1	—	—	1	2	16	18
2	1	—	1	—	3	5	4	9
3	—	—	—	—	1	1	2	3
4	2	— (1)	1	—	6	9 (1)	45 (1)	54 (2)
5	—	—	—	—	1	1	8	9
6	—	—	—	—	2	2	12	14
Total ..	3	1 (1)	2	—	14	20 (1)	87 (1)	107 (2)

Figures in brackets denote eggs of *D. violescens*.